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LANDSCAPE DYNAMICS ANALYSIS IN IAŞI METROPOLITAN AREA (ROMANIA) USING REMOTE SENSING DATA

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Landscape dynamics analysis in Iași Metropolitan Area (Romania) using remote sensing data.

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Analiza dinamicii peisajului în Zona Metropolitană Iași cu ajutorul imaginilor satelitare. Lucrarea de față își propune observarea și cuantificarea modificărilor survenite în modul de utilizare a terenurilor în Zona Metropolitană Iași în perioada 1993-2009. În centrul analizei se situează dinamica spațiului construit, prin identificarea traiectoriilor sale de extindere și cuantificarea modificărilor sale de structură cu ajutorul metricilor peisajului. În scopul extragerii datelor referitoare la modul de utilizare a terenului, s-a apelat la manipularea complexă a imaginilor satelitare Landsat, cu realizarea unor clasificări tematice supervizate, precum și a indicelui normalizat al vegetației (NDVI). Lucrarea se încheie prin efectuarea unei analize statistice sintetice a dinamicii modificărilor, efectuată la nivel de comună, în scopul realizării unor comparații între unitățile administrative în funcție de intensitatea dinamicii modificării utilizării terenurilor.

Cuvinte cheie : dinamica spațiului construit, imagini satelitare, clasificare supervizata, metrici ale peisajului, indice de vegetație, indicatori sintetici,

Landscape dynamics analysis in Iași Metropolitan Area (Romania) using remote sensing data. The present paper focuses on the observation and quantification of land cover changes in Iasi Metropolitan Area during 1993-2009. The analysis is centered upon the built-up space dynamics and includes the detection of its extension directions and the measurement of its structural changes by landscape metrics. In order to obtain the land cover data, some remote sensing images were processed by supervised classification and Normalized Difference Vegetation Index (NDVI). In the end of the study, a synthetic statistical analysis of the change dynamics is performed at commune level, in order to compare the administrative units by the intensity of land cover dynamics.

Key words: built-up space dynamics, remote sensing images, supervised classification, landscape metrics, vegetation index, synthetic indicators

1. INTRODUCTION

a. Brief theoretical framing

Landcover changes caused by urban growth represent a very actual theme of research and one of the most appropriate data sources for this type of anlysis is remote sensing images. Monitoring landcover change in the proximity of urban areas can satisfactory describe the patterns of landscape dynamics [1]. Landscape dynamics intensity is strongly increased in urban periphery, by the accelerate development of dispersed residential areas due to the economic, social and environmental benefits proved by these peripheries accompanied by the increase in population mobility [2]. In Romania, this phenomena was strongly enhanced by the liberalization of political and economical life after 1990. The urban sprawl is is often associated with the outburst of residential areas outside the limits of the buit-up areas created during communist period, and the most common sprawl type in Romanian towns is the one alongside the major roads [3].

b. Study area and hypothesis

Iasi Metropolitan Area was estabilshed in 2004 and counts 13 communes surrounding Iasi city. It representents a densely populated area, as it was inhabited, in 2009, by 400.323 people (47.81% of county population) on his area of 808 km^2 (only 14.74% of county surface) [4]. Consequently, we can issue the hypothesis that Iasi Metropolitan Area suffers from a considerable level of demographic pressure and has been obviously affected by land cover changes during last 20 years. Hence the present paper focuses especially on the study of landscape dynamics in the study area - as it represents the periphery of Iasi city and it follows the specific pattern for such an area - rather than on assessing the cultural-territorial or functional-administrative relevance and efficiency of this metropolitan area.

c. Objectives

The present study is centered upon two types of objectives: methodological and study-area focused. Therefore, the complex handling of satellite imagery, accompanied by supervised classification accuracy testing, in order to extract a precise, high-quality land cover represents our first approach. At the same time, we intended to draw certain conclusions concerning the landscape dynamics in Iasi Metropolitan Area, by statistical analysis of the resulted vector data.

2. MATERIALS AND METHODS

The analysis was based on remote sensing images Landsat Thematic Mapper (30 × 30 m) from 3 years: 1993, 2006 and 2009 – taken in June/July [5]. Initially, an image from 2000 was also included, but as it was taken during the autumn, the land cover aspect was enough different to generate errors in latter comparisons. The communes limits for the study area as vector shapefile format were also used.

In order to manipulate remote sensing data and resulted vector data, we used several software programs: Envi 5 – for image processing, Global Mapper 12 – for format and project conversion of files, ArcGIS 9.3.1, including Patch Analyst extension [6] – for vector analysis and mapping of results and Microsoft Office Excel 2010 – for landscape metrics selection and graphical representation.

a. Image processing

The extraction of land cover from remote sensing images involved three main types of operations: preprocessing including Dark-Object Subtraction, supervised classification and accuracy assessment test by confusion matrix. At the same time, a Normalized Difference Vegetation Index was performed, aimed to highlight the changes in vegetation land cover.

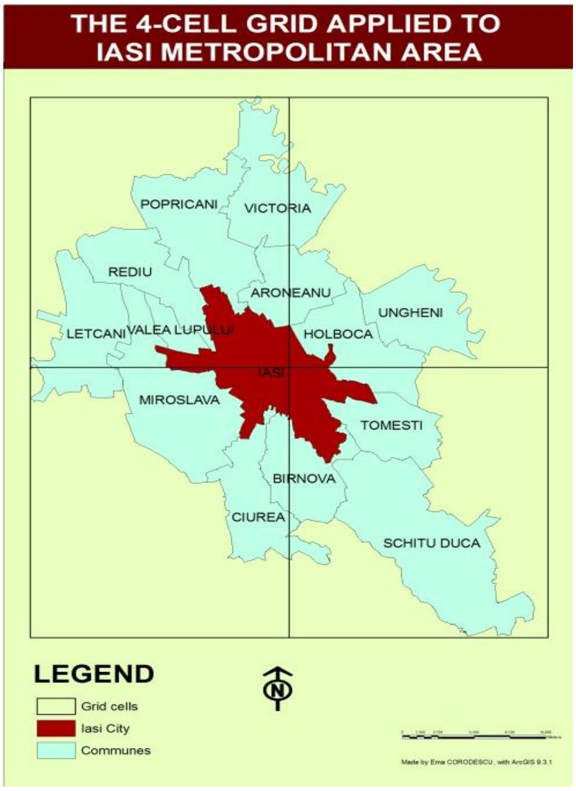

Figure 1. The grid used for calculating landscape metrics

The supervised classification was the most complex and important part of the image processing. Four land cover classes were created: BUILT-UP AREAS, FARMLAND, FOREST and WATER. Maximum Likelihood method was chosen, method which assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class [7]. Firstly, several Training Areas for each class (approximately 150 in total) were digitized on-screen, using 432, 471 and 321 composites. These TA represent well-known areas, studied by fieldwork and scattered within the study area. After this step, the computer used the spectral respond of each class of Training Areas to recognize similar areas and included it in an

Landscape metric	Description	Formulae
Patch Size Coefficient of Variance (PSCoV)	-calculates the coefficient of variance of the patch (i.e. individual object/polygon resulted form image classification) area	$\mathbf{PSCoV} = \frac{PSSD}{MPS} \times \mathbf{100}$ *PSSD – patch size (area) standard deviation* *MPS – mean patch size (area)*
Mean Patch Edge (MPE)	-calculates the average amount of edge (perimeter) per patch	$\mathbf{MPE} = \frac{TE}{NP}$ *TE – total edge for all patches (perimeter length)* *NP – number of patches*
Area Weighted Mean Shape Index (AWMSI)	-it increases with the patch shape irregularity	$\mathbf{AWMSI} = \frac{\sum_{i=1}^{n} \frac{PE_i}{PS_i^2}}{NP}$ PE_i *– each patch permieter (patch egde)* PS_i*- each patch area (patch size)*

Table 1. The characteristics of used landscape metrics [9]

adequate class. The results were converted to vector Shapefile format. The Kappa index resulted from the accuracy assessment test performed had high values, proving the precision of the resulted land cover: 93.86% for 1993, 91.61% for 2006 and 95.97% for 2009

b. Landscape metrics calculations

Landscape metrics represent are a valuable tool to quantify the spatial landscape properties [8]. From the various type of metrics available, we chose 3 simple metrics (Table 1), computed for the 4 cells of the grid applied to the Iasi Metropolitan Area (Figure 1) and at class level (i.e. for each land cover class).

c. Land cover change statistics

In order to measure the intensity in land cover change at commune level, two dynamic land use indicator were calculated (Table 2).

Before calculating these indicators, several basic vector operations were made, in order to provide the necessary data (Figure 2). After calculating, a synthetic map including these indicators was performed.

Indicator name	Formulae
Dynamic Land Use Indicator [10]	**K =** $\frac{U_2-U_1}{U_1 T}\times 100$ **(%)** *U_1 , U_2 – areas covered with a specific land use class at the start and end date respectively* *T – period of time (years)*
Synthetic Dynamic Land Use Indicator [11]	**LC =** $\frac{\sum_{i=1}^{n}\lvert\Delta LU_{i-j}\rvert}{2\sum LU_i}\times\frac{1}{T}\times 100$ **(%)** *ΔLU_{i-j} –the transition area from the i^{th} land cover class to other land cover classes* *LU_i – the area of the i^{th} land cover at the starting date* *T – period of time (years)*

Table 2. Land cover change indicators

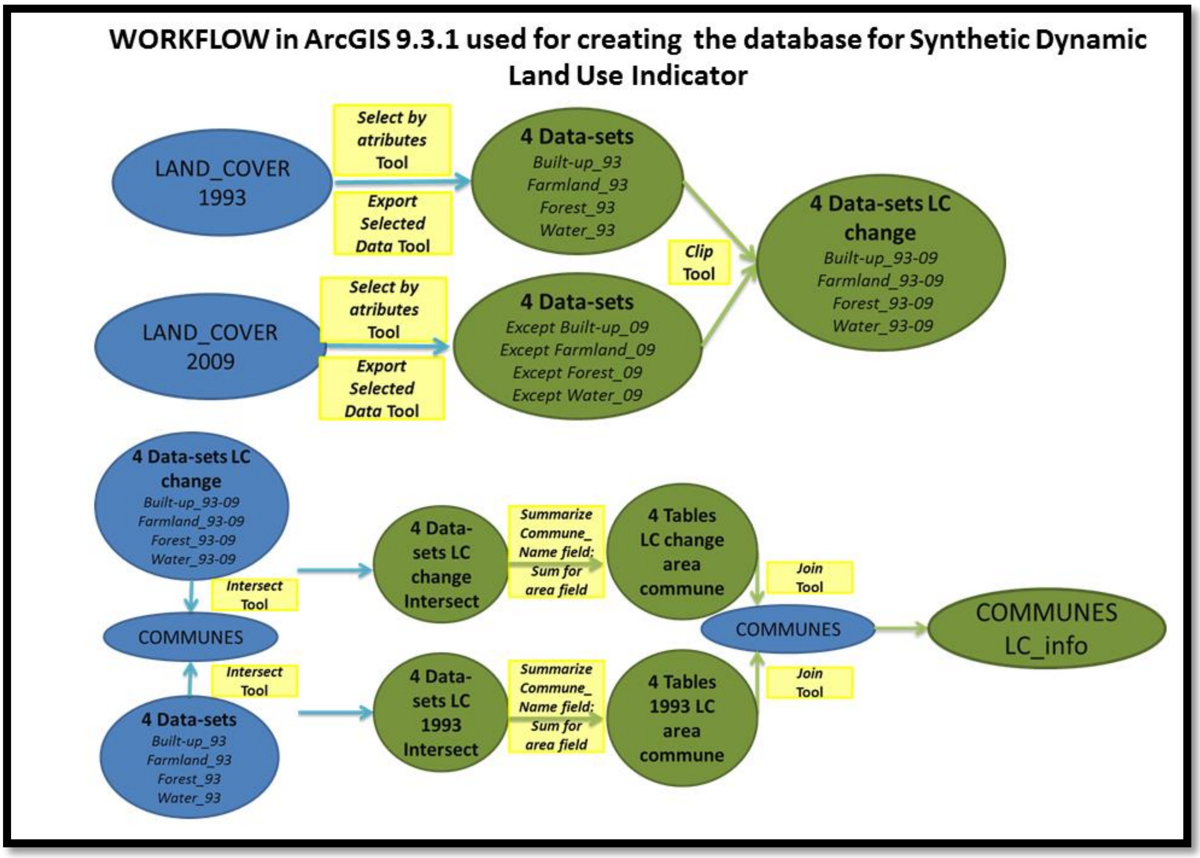

Figure 2. Workflow performed for creating the necessary geodatabase for calculating Synthetic Dynamic Land Use Indicator

3. RESULTS

a. Mapping of land cover

The first result of the present study consists in 3 land cover maps for the Iasi Metropolitan Area , by which it can offer a general view over the patterns of land cover change during 1993-2009.

The most obvious changes concerned the built-up areas, that experienced a 36.61% increase in their total area. This increase follows a tentacular pattern, new buildings having been located along the main road transport networks – fitting the old type of extension specific for the Iasi city (very visible starting from the end of 18^{th} century), conditioned by natural and socio-economic factors [12]. Several directions were preferred in this respect (Figure 3).

- W-NW axis – which overlaps the E583 route (Valea Lupului, Northern part of Miroslava and Letcani communes) – is characterized by a strong commercial specialization (supermarkets, shopping malls, car dealerships, building materials stores) accompanied by some few new industrial units. The development of this axis was relatively uniform and continuous, leaving few empty spaces between the large buildings placed here.
- 2 axels in the southern part of the city: former industrial area of CUG and its extensions in Miroslava and Ciurea communes, containing both old factories, some of them reconverted into business centers and new residential developments (in this area, the residential followed not only the major transport network, but also the new roads especially built in large-scale, private real estate projects) and Bucium axis with its extensions in Birnova commune (DN24 Iasi-Vaslui) - having experienced a more sprawl development (mainly determined by the rough topography of the Birlad Plateau), almost entirely with residential functions.
- South-east axis (Tomești commune) – residential and former industrial units conversed into building materials dealerships.
- A more sparse development in the northern part of the city, centered upon the Copou-Breazu axis and consisting in residential areas.

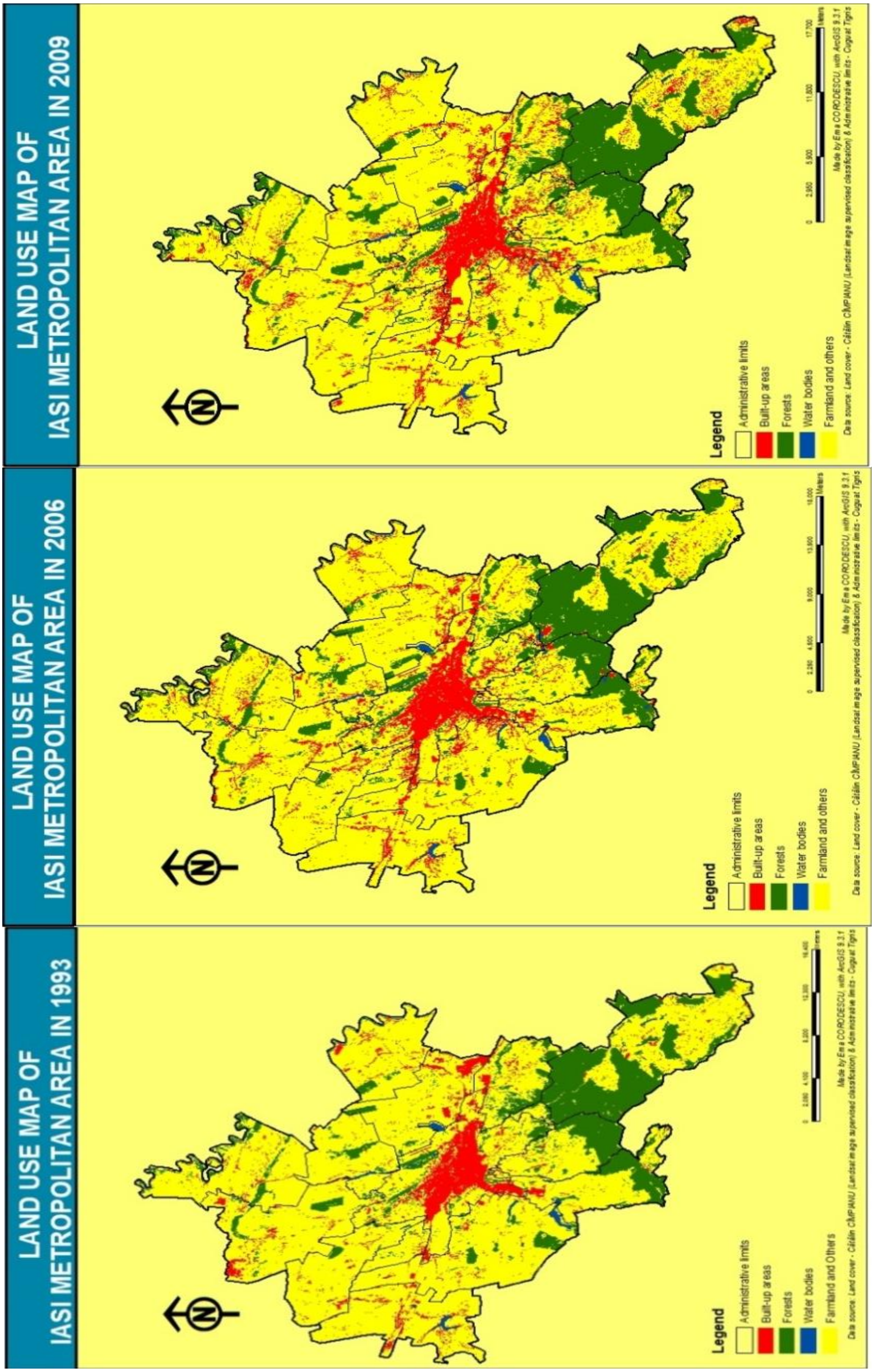

Figure 3. Land use maps of Iasi Metropolitan Area 1993-2009

It is easy to observe that the extension of built-up areas especially affected farmland and other land use, rather than forest areas. Furthermore, a slight increase in the forest surfaces (9.5%) can be observed. This increase is almost due to the living of farmland after the communist period and the development of secondary shrub vegetation (having a similar spectral response as forest areas) on the resulted bare soil.

b. Landscape metrics

Landscape metrics represent a complementary tool for comparing the patterns of change. Only landscape metrics concerning built-up area were included in analysis, as this was the most dynamic land cover class and, at the same time, it has a satisfactory explanatory power for the others classes.

Patch size coefficient of variance (Figure 4) measures the compact built-up areas (i.e. patches) deviations from the mean value. Hence, it is able to highlight existing differences in built-up areas density across every cell considered by the grid presented in methodology. The general trend of decrease is explained by the intense extension of built-up space inside the communes, determining a balance, at each cell level, between dense, continuous urban built-up space from Iasi City (consisting in large patches) and discontinuous built-up space in rural areas (consisting in small patches). The most obvious decrease, also characterized by the greatest values all over the studied period is the north-east area, clearly detached from the others. This difference is due to more factors: first of all, this cell contains the smallest area of the Iasi Metropolitan Area (and, at the same time, the smallest area of built-up space), determining a lower statistical precision; moreover, this some industrial units (consisting in large patches), and

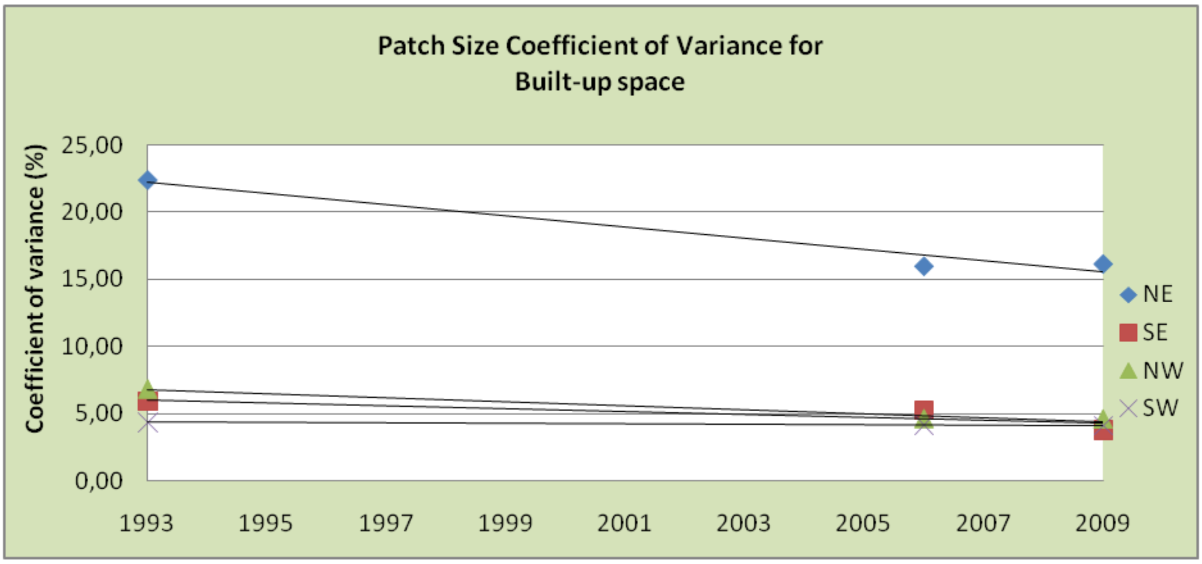

Figure 4. Patch Size coefficient of Variance for Built-up space in Iasi Metropolitan Area between 1993-2009

extended areas of village estates, characterized by very sparse built-up areas (very small patches).

A more accurate view over the patterns of built-up space extension is proved by the Mean Patch Edge (Figure 5) and Area Weighted Mean Shape Index (Figure 6). Both

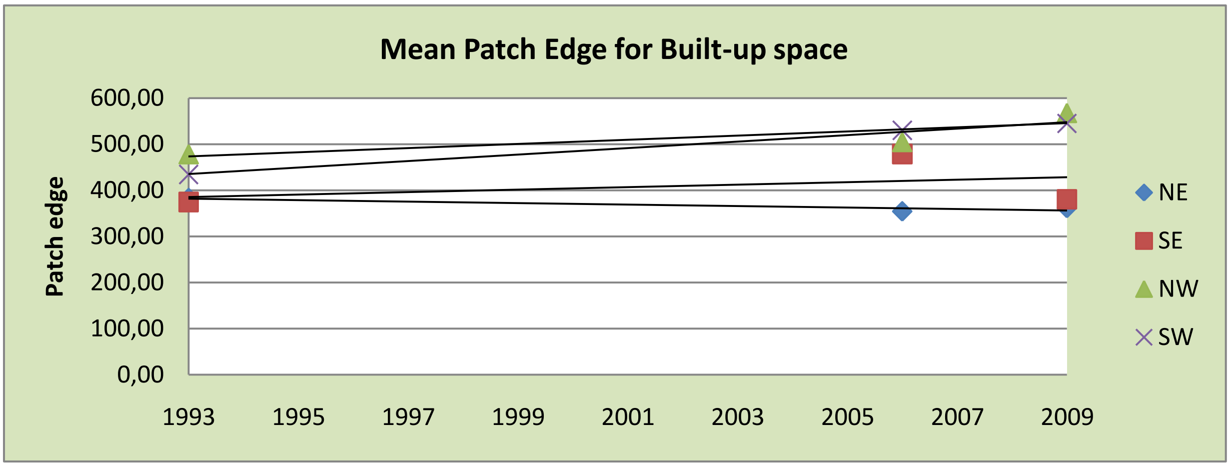

Figure 5. Mean Patch Edge for Built-up space in Iasi Metropolitan Area between 1993-2009

indexes concern the form of the elementary polygons (patches), being capable of measuring the shape regularity of the built-up patches. Mean Patch Edge experienced general tendency of increase, due to the axial and starry expansion; however, this index is very sensitive at patch area value, which can considerably influence it. The slight decrease of this indicator for the north-eastern area is explained again by the specific conditions above mentioned.

The highest explanatory value is offered by the last index, Area Weighted Mean Shape Index, which exactly express the degree of shape regularity. Apart from its general tendency to rise during the studied period, specific characteristics for each part of the Iasi Metropolitan Area should be stated. South-west area had the highest values and the sharpest rise, as it was , affected almost entirely by residential developments, which followed an irregular, dispersed pattern adapted to local topography, road networks and proximity to basic services. South-east and Nord-west parts also experienced a sharp increase, having been very dynamic both in large-scale developments and individual residential. The lower values of this indexes (compared to the south-west area) are due to the intake of compactness and geometric regularity brought by large-scale constructions (commercial units - in north-west and real-estate projects - in south-east). Finally, the north-east cell had the lowest values and the lowest rate of increase, due to its reduced surface and dynamics.

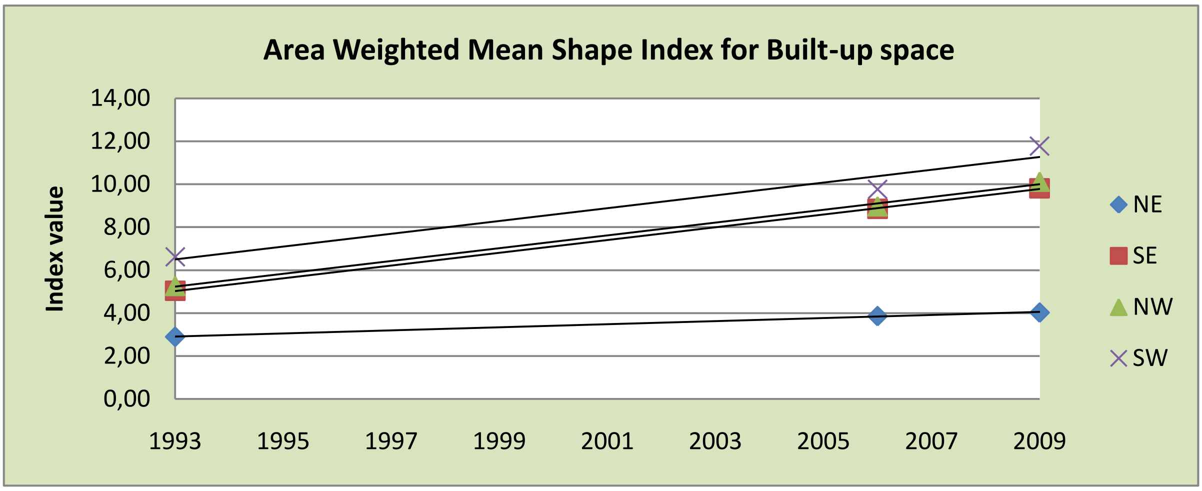

Figure 6. Area Weighted Mean Shape Index for Built-up space in Iasi Metropolitan Area between 1993-2009

c. Vegetation change

A brief analysis was conducted upon the vegetation change, by means of Normalized Difference Vegetation Index, performed on remote sensing data (figure 7). Several conclusion can be drawn from these maps:

- The general pattern of vegetation cover respects the pattern of general land cover extracted from classification
- The areas highly affected built-up space extension experienced vegetation loss (many former areas situated in proximity of Iasi city, with moderate vegetation in 1993 had sparse vegetation or no vegetation in 2009).
- The areas situated further away from the new built-up areas experienced an increase in vegetation density, due to the natural recovery of abandoned agricultural land (especially in north and north-west part, where many areas having sparse vegetation in 1993 have moderate vegetation in 2009).

- Vegetation loss had also high values in Iasi city, where many areas with sparse vegetation in 1993 had no vegetation in 2009, due to the infill growth of the city.

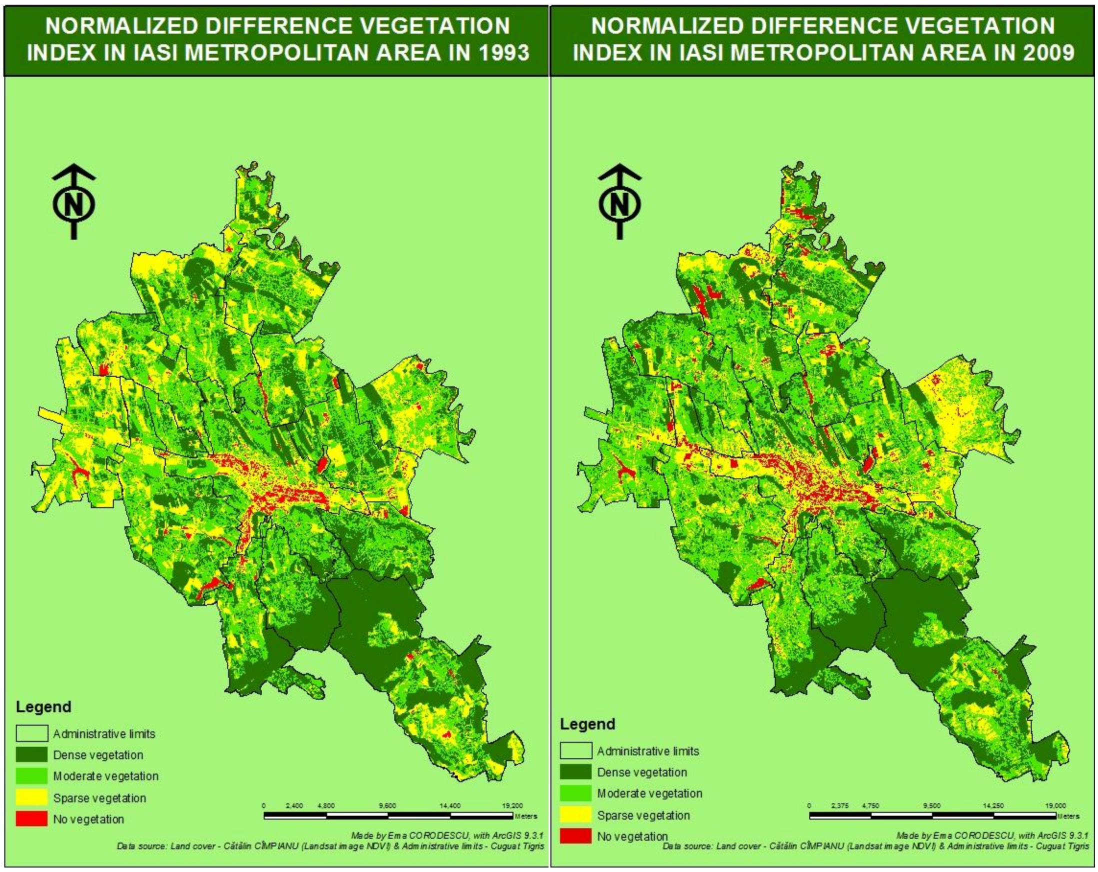

Figure 7. Normalized Difference Vegetation Index in Iasi Metropolitan Area in 1993 and 2009

d. Land cover change statistics

In order to compare the general patterns of land cover change in administrative units of Iasi Metropolitan Area, two dynamic land use change indicators were calculated and the results were mapped (figure 8).

The first indicator, Land Use Dynamic Indicator (calculated for each land cover class) shows the following aspects:

- Built-up area increased in all communes, excepting Holboca and Ungheni; the most dynamic communes are situated around the Iasi city: Valea Lupului, Miroslava, Ciurea, Birnova, Tomesti
- Farmland area decreased in all communes, after the after the destruction of the communist collective farm holdings.
- Forest area increased in almost all communes, as a great part of the former agricultural land turned into shrub secondary vegetation, often having the same spectral response as forest.

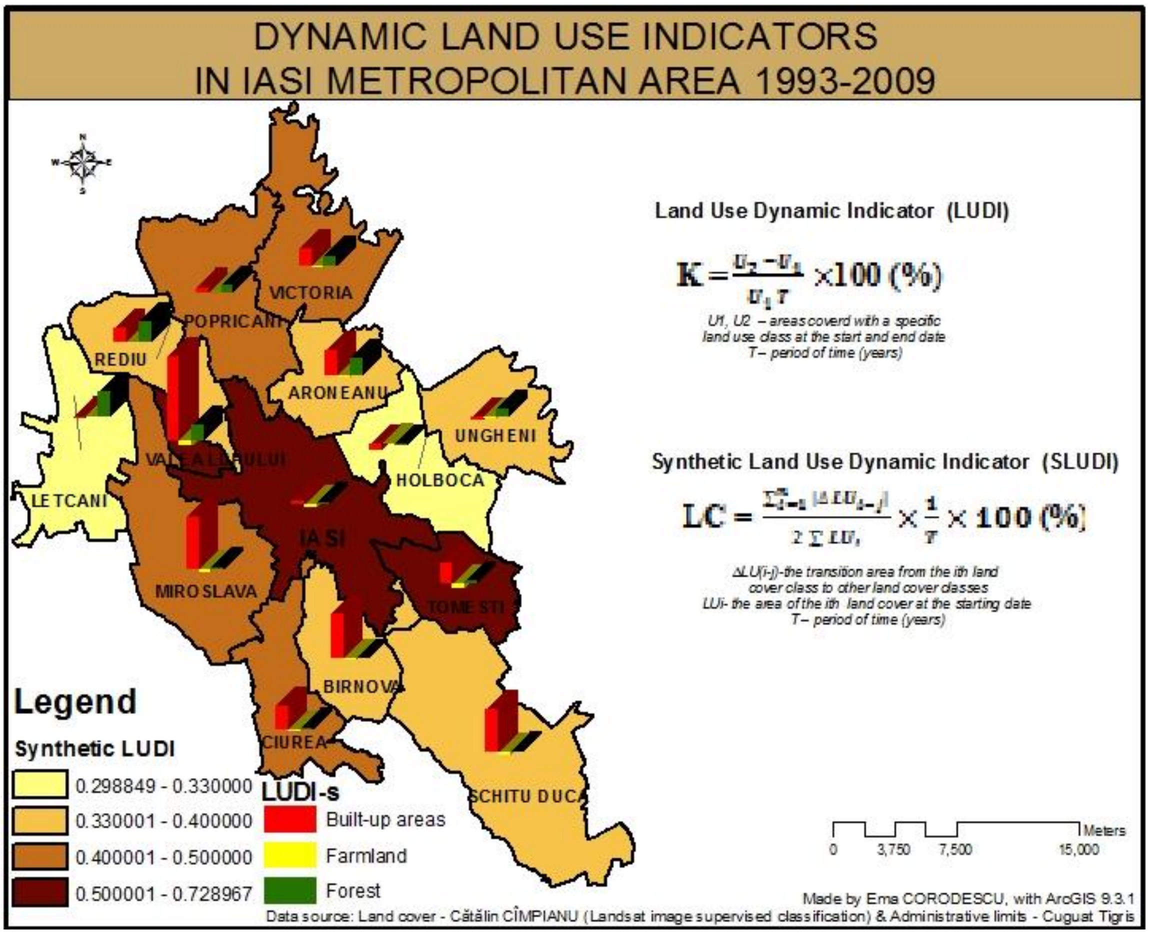

Figure 8. Dynamic land use indicators in Iași Metropolitan Area (1993-2009)

- Water bodies dynamics was not mapped, as they did not suffered major changes across the studied period.

The second indicator, Synthetic Land Use Dynamic Indicator, considers the dynamics of all land cover classes, offering an integral vision over each administrative unit. The highest values are specific for Iasi city and two surrounding communes (Tomesti and Valea Lupului – with an important residential development, accompanied by a sharp decrease in farmland and a slight increase in forest areas). The second group includes 4 communes (Miroslava, Ciurea, Popricani and Victoria), having a great increase in built-up areas too. A more numerous group has lower values: Rediu and Aroneanu experienced a certain increase in built-up areas, especially by developing leisure and tourism facilities; Birnova, in spite of its proximity to the city is characterized by this lower value, as the general unsuitable topographic setting (steep slopes, often affected by landslides) and the presence of forest, permitted neither the conversion of large areas of bare soil into farmland before 1990, nor the extension of built-up areas to great surfaces; Schitu Duca occupied by the greatest part of the Birnova-Repedea Forest, which represent a protected area and Ungheni, that is an inaccessible area. The last class includes two communes: Letcani (situated a bit far from the Iasi city and continuing to exploiting its farmland rather than converting it into other uses) and Holboca (inaccessibly situated at the eastern periphery of Iasi city).

4. CONCLUSIONS

Iasi Metropolitan Area encountered important land cover changes during the last twenty years. An eventual future analysis of different census data (economic, demographic, land use etc.) may reveal serious inconsistences and dysfunctionalities. It is obvious that the present observed dynamics represent the result of an uncontrolled evolution. Consequently, urgent measures should be taken concerning the land management, in order to satisfy, at the same time, an economically profitable exploitation of the land, capable of improving the living standard of the population and the rigors of a proper conservation of the natural ecosystems.

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